

[NAME OF DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION]

DIELECTRIC PASTE FOR SPACER LAYER OF A MULTI-LAYERED  
CERAMIC ELECTRONIC COMPONENT

5

[FIELD OF THE INVENTION]

[0001]

The present invention relates to a dielectric paste adapted for forming a spacer layer of a multi-layered ceramic electronic component, and particularly to a dielectric paste adapted for forming a spacer layer of a multi-layered ceramic electronic component which does not dissolve a binder contained in a layer adjacent to the spacer layer of the multi-layered ceramic electronic component and can reliably prevent defects from being generated in a multi-layered ceramic electronic component.

15

[BACKGROUND OF THE INVENTION]

[0002]

Recently, the need to downsize various electronic devices makes it necessary to downsize the electronic components incorporated in the devices and improve the performance thereof. Also in multi-layered ceramic electronic components, such as multi-layered ceramic capacitors, it is strongly required to increase the number of layers and make the laminated unit thinner.

25

[0003]

When a multi-layered ceramic electronic component as typified by a multi-layered ceramic capacitor is to be manufactured, ceramic powders, a binder such as an acrylic system resin, a butyral resin or the like, a

plasticizing agent such as a phthalate ester, glycol, adipate ester, phosphate ester or the like, and an organic solvent such as toluene, methyl ethyl ketone, acetone or the like are mixed and dispersed, thereby preparing a dielectric paste for a ceramic green sheet.

5 [0004]

The dielectric paste is then applied onto a support sheet made of polyethylene terephthalate (PET), polypropylene (PP) or the like using an extrusion coater, a gravure coater or the like to form a coating layer and the coating layer is heated to dryness, thereby fabricating a ceramic green  
10 sheet.

[0005]

Further, a conductive powder of nickel or the like and a binder are dissolved into a solvent such as terpineol, thereby preparing a conductive paste and the thus prepared conductive paste is printed on the ceramic  
15 green sheet in a predetermined pattern using a screen printing machine and dried, thereby forming an electrode layer.

[0006]

When the electrode layer has been formed, the ceramic green sheet on which the electrode layer is formed is peeled off from the support sheet  
20 to form a multi-layered unit including the ceramic green sheet and the electrode layer. Then, a ceramic green chip is formed by laminating a desired number of the multi-layered units to form the laminated body, pressing the laminated body and dicing the laminated body.

[0007]

25 Finally, the binder is removed from the green chip, the green chip is baked and an external electrode is formed, thereby completing a multi-layered ceramic electronic component such as a multi-layered ceramic capacitor.

[0008]

At present, the need to downsize electronic components and improve the performance thereof makes it necessary to set the thickness of the ceramic green sheet determining the spacing between layers of a multi-layered ceramic capacitor to be equal to or smaller than 3  $\mu\text{m}$  or 2  $\mu\text{m}$  and to laminate three hundred or more multi-layered units each including a ceramic green sheet and an electrode layer.

[0009]

However, in a conventional multi-layered ceramic capacitor, since an electrode layer is formed on the ceramic green sheet in a predetermined pattern, a step is formed between the surface of the electrode layer and the surface of the ceramic green sheet where no electrode layer is formed. Therefore, in the case of laminating a number of multi-layered units each including a ceramic green sheet and an electrode layer, it is difficult to bond the ceramic green sheets included in the number of multi-layered units in a desired manner so that the laminated body fabricated by laminating the number of multi-layered units is often deformed and delamination of layers sometimes occurs.

[0010]

In order to solve these problems, it has been proposed to eliminate steps on the surface of the ceramic green sheet by printing a dielectric paste on the surface of the ceramic green sheet in a complementary pattern to that of the electrode layer, thereby forming a spacer layer between neighboring electrode layers.

[0011]

In the case where the spacer layer is printed on the ceramic green sheet between neighboring electrode layers in this manner, thereby fabricating the multi-layered unit, steps on the surface of the ceramic

green sheet of each multi-layered unit can be eliminated and even in the case of laminating a number of multi-layered units each including a ceramic green sheet and an electrode layers and fabricating a multi-layered ceramic capacitor, it is possible to bond the ceramic green sheets included in the number of multi-layered units in a desired manner and it is possible to prevent the laminated body fabricated by laminating a number of multi-layered units each including the ceramic green sheet and the electrode layer from being deformed.

## 10 [DISCLOSURE OF THE INVENTION]

### [PROBLEMS TO BE SOLVED BY THE INVENTION]

[0012]

However, in the case where a spacer layer is formed by printing a dielectric paste prepared using terpeneol, which is highly popular as a solvent for a dielectric paste, on a ceramic green sheet formed using a butyral system resin, which is the most popular binder for a ceramic green sheet, the binder contained in the ceramic green sheet is dissolved by terpeneol contained in the dielectric paste and the ceramic green sheet is swollen or partially dissolved, whereby voids are generated at the interface between the ceramic green sheet and the spacer layer or fissures or wrinkles are generated on the surface of the spacer layer. As a result, in the case where a multi-layered ceramic capacitor is fabricated by laminating a number of multi-layered units to fabricate a laminated body and baking the laminated body, voids are generated in the multi-layered ceramic capacitor. Further, in the case where fissures or wrinkles are generated on the surface of the spacer layer, since the portions of the spacer layer where fissures or wrinkles are generated tend to drop off, when a number of multi-layered units are laminated to fabricate a

laminated body, the portions of the spacer layer where fissures or wrinkles are generated mix into the laminated body as a foreign substance, thereby causing internal defects in the multi-layered ceramic capacitor and generating voids at portions where the spacer layer is  
5 missing.

[0013]

One proposed solution for these problems is to employ a hydrocarbon system solvent such as kerosene, decane or the like as the solvent. However, since a hydrocarbon system solvent such as kerosene,  
10 decane or the like does not dissolve the binder component used for the dielectric paste, it is impossible to completely replace the conventional solvent such as terpeneol with a hydrocarbon system solvent such as kerosene, decane or the like. Therefore, since the butyral system resin contained in the ceramic green sheet as a binder is still soluble in the  
15 solvent contained in the dielectric paste to some extent, it is difficult to prevent generation of pinholes and cracks in the ceramic green sheet in the case where the ceramic green sheet is very thin, and since the viscosity of a hydrocarbon system solvent such as kerosene, decane or the like is lower than that of terpeneol, it is difficult to control the viscosity of  
20 the conductive paste.

[0014]

Further, Japanese Patent Application Laid Open No. 5-325633, Japanese Patent Application Laid Open No. 7-21833 and Japanese Patent Application Laid Open No. 7-21832 propose use of a hydrogenated  
25 terpeneol such as dihydroterpeneol or a terpene system solvent such as dihydroterpeneol acetate instead of terpeneol as a solvent. However, since the butyral system resin contained in the ceramic green sheet as a binder is also soluble in a hydrogenated terpeneol such as dihydroterpeneol or a

terpene system solvent such as dihydroterpineol acetate to some extent, it is difficult to prevent generation of pinholes and cracks in a ceramic green sheet in the case where the ceramic green sheet is very thin.

[0015]

5 It is therefore an object of the present invention to provide a dielectric paste adapted for forming a spacer layer of a multi-layered ceramic electronic component which does not dissolve a binder contained in a layer adjacent to the spacer layer of the multi-layered ceramic electronic component and can reliably prevent defects from being  
10 generated in a multi-layered ceramic electronic component.

#### [MEANS FOR SOLVING THE PROBLEMS]

[0016]

The inventors of the present invention vigorously pursued a study  
15 for accomplishing the above objects and, as a result, made the discovery that in the case where a dielectric paste for forming a spacer layer was prepared using an acrylic system resin as a binder and at least one solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate,  
20 and d-dihydrocarvyl acetate as a solvent, it was possible to dissolve the binder in the solvent in a desired manner and even when the dielectric paste was printed on a ceramic green sheet containing a butyral system resin as a binder, thereby forming a spacer layer, the binder contained in the ceramic green sheet was not dissolved in the solvent contained in the  
25 dielectric paste and it was therefore possible to reliably prevent the ceramic green sheet from being swollen or partially dissolved so as to generate voids at the interface between the ceramic green sheet and the spacer layer or generate fissures or wrinkles on the surface of the spacer

layer, and it was therefore possible to effectively prevent voids from being generated in a multi-layered ceramic electronic component such as a multi-layered ceramic capacitor.

[0017]

5           The present invention is based on these findings and therefore, the objects of the present invention can be accomplished by a dielectric paste adapted for forming a spacer layer and containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone,  
10   l-perillyl acetate, l-carvyl acetate, and d- dihydrocarvyl acetate as a solvent.

[0018]

          In the present invention, a dielectric paste for a spacer layer is prepared by kneading a dielectric material (ceramic powder) and an  
15   organic vehicle obtained by dissolving an acrylic system resin into an organic solvent.

[0019]

          The dielectric material can be selected from among various compounds capable of forming a composite oxide or oxide, such as a  
20   carbonate, nitrate, hydroxide, organic metallic compound and the like and mixtures thereof. It is preferable to use a dielectric powder having the same composition as that of a dielectric powder contained in a ceramic green sheet described later. The dielectric material is normally used in the form of a powder whose average particle diameter is about 0.1  $\mu\text{m}$  to  
25   about 3.0  $\mu\text{m}$ .

[0020]

          In the present invention, it is preferable for the weight-average molecular weight of an acrylic system resin contained as a binder in the

dielectric paste for forming a spacer layer to be equal to or larger than 450,000 and equal to or smaller than 900,000 and in the case where an acrylic system resin whose weight-average molecular weight is equal to or larger than 450,000 and equal to or smaller than 900,000 is employed as  
5 the binder of a dielectric paste for forming a spacer layer, it is possible to prepare a dielectric paste for forming a spacer layer so as to have a desired viscosity.

[0021]

In the present invention, it is preferable for the acid value of an  
10 acrylic system resin contained as a binder in the dielectric paste for forming a spacer layer to be equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g and in the case where an acrylic system resin whose acid value is equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g is employed as the binder of a dielectric  
15 paste for forming a spacer layer, it is possible to prepare a dielectric paste for forming a spacer layer so as to have a desired viscosity.

[0022]

The dielectric paste for forming a spacer layer preferably contains about 2.5 weight parts to about 15 weight parts, more preferably, about  
20 2.5 weight parts to about 6 weight parts of a butyral system resin and preferably contains 70 weight parts to about 320 weight parts, more preferably, 70 weight parts to about 200 weight parts, most preferably, 70 weight parts to about 150 weight parts of a solvent with respect to 100 weight parts of a powder of a dielectric raw material.

25 [0023]

The dielectric paste for forming a spacer layer contains, in addition to the powder of a dielectric raw material and the acrylic system resin, optionally, a plasticizing agent and a release agent.



[0024]

The plasticizing agent contained in the dielectric paste for forming a spacer layer is not particularly limited and illustrative examples thereof include phthalate ester, adipic acid, phosphate ester, glycols and the like.

5 The plasticizing agent contained in the dielectric paste for forming a spacer layer may or may not belong to the same plasticizing agent group as that of a plasticizing agent contained in a ceramic green sheet described later. The dielectric paste for forming a spacer layer contains the plasticizing agent in an amount of about 0 weight part to about 200  
10 weight parts with respect to 100 weight parts of the acrylic system resin, preferably in an amount of about 20 weight parts to about 200 weight parts, most preferably in an amount of about 50 weight parts to about 100 weight parts.

[0025]

15 The release agent contained in the dielectric paste for forming a spacer layer is not particularly limited and illustrative examples thereof include paraffin, wax, silicone oil and the like. The dielectric paste for forming a spacer layer contains the releasing agent preferably in an amount of about 0 weight % to about 100 weight % with respect to 100  
20 weight parts of the acrylic system resin, preferably in an amount of about 2 weight parts to about 50 weight parts, more preferably in an amount of about 5 weight parts to about 20 weight parts.

[0026]

Further, in a study done by the inventors of the present invention,  
25 it was found that in the case of printing a conductive paste on a very thin ceramic green sheet to form an electrode layer and printing a dielectric paste on the very thin ceramic green sheet to form a spacer layer, the solvent contained in the conductive paste for forming the electrode layer

and the solvent contained in the dielectric paste for forming the spacer layer dissolved or swelled a binder component contained in the ceramic green sheet and, on the other hand, the conductive paste and the dielectric paste permeated into the ceramic green sheet, thereby causing short circuit failure and that, therefore, it was preferable to form an electrode layer and a spacer layer on a support sheet separately from the ceramic green sheet and bond them onto the surface of the ceramic green sheet via an adhesive layer after drying them. However, in the case where the electrode layer and the spacer layer are formed on the support sheet separately from the ceramic green sheet in this manner, in order to make the support sheet easy to peel off from the electrode layer and the spacer layer, it is preferable to form a release layer containing the same binder as that contained in the ceramic green sheet on the support sheet, print a conductive paste on the release layer, thereby forming an electrode layer, and print a dielectric paste on the release layer, thereby forming a spacer layer. Even in the case of printing a conductive paste on the release layer containing the same binder as that contained in the ceramic green sheet to form an electrode layer and printing a dielectric paste on the release layer to form a spacer layer, when the release layer contains a butyral system resin as a binder and the dielectric paste contains terpineol as a solvent, the binder contained in the release layer is dissolved by the solvents contained in the dielectric paste so that the release layer is swollen or partially dissolved, whereby voids are generated at the interface between the ceramic green sheet and the spacer layer or fissures or wrinkles are generated on the surface of the spacer layer. As a result, in the case where a multi-layered ceramic capacitor is fabricated by laminating a number of multi-layered units to fabricate a laminated body and baking the laminated body, voids are generated in the multi-layered

ceramic capacitor. Furthermore, in the case where fissures or wrinkles are generated on the surface of the spacer layer, since the portions of the spacer layer where fissures or wrinkles are generated tend drop off, when a number of multi-layered units are laminated to fabricate a laminated body, the portions of the spacer layer where fissures or wrinkles are generated mix into the laminated body as a foreign substance, thereby causing internal defects in the multi-layered ceramic capacitor and generating voids at portions where the spacer layer was missing.

[0027]

However, according to the present invention, the dielectric paste for forming a spacer layer contains an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d-dihydrocarvyl acetate as a solvent and the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d-dihydrocarvyl acetate hardly dissolves a butyral system resin contained in the ceramic green sheet as a binder. Therefore, even in the case of forming a release layer containing the same binder as that contained in the ceramic green sheet and printing a dielectric paste on the release layer to form a spacer layer, it is possible to reliably prevent the release layer from being swollen or partially dissolved so as to generate voids at the interface between the release layer and the spacer layer or generate fissures or wrinkles on the surface of the spacer layer and it is therefore possible to effectively prevent defects from being generated in a multi-layered ceramic electronic component such as a multi-layered ceramic capacitor.

## **[TECHNICAL ADVANTAGES OF THE INVENTION]**

[0028]

According to the present invention, it is possible to provide a dielectric paste for a spacer layer of a multi-layered ceramic electronic component which does not dissolve a binder contained in a layer adjacent to the spacer layer of the multi-layered ceramic electronic component and can reliably prevent defects from being generated in a multi-layered ceramic electronic component.

## **10 [DESCRIPTION OF THE PREFERRED EMBODIMENTS]**

[0029]

In a preferred embodiment of the present invention, a dielectric paste for a ceramic green sheet which contains a butyral system resin as a binder is first prepared and is applied onto a long support sheet using an extrusion coater or a wire bar coater, thereby forming a coating layer.

[0030]

A dielectric paste for forming a ceramic green sheet is normally prepared by kneading a dielectric material (ceramic powder) and an organic vehicle obtained by dissolving a butyral system resin into an organic solvent.

[0031]

It is preferable for the degree of polymerization of a butyral system resin to be equal to or larger than 1000 and equal to or smaller than 2600 and it is preferable for the degree of butyralization of a butyral system resin contained in the conductive paste to be equal to or larger than 64 mol % and equal to or smaller than 78 mol %.

[0032]

An organic solvent used for preparing the organic vehicle is not

particularly limited and an organic solvent such as terpineol, butyl carbitol, acetone, toluene, ethyl acetate and the like can be used for preparing the organic vehicle.

[0033]

5           The dielectric material can be selected from among various compounds capable of forming a composite oxide or oxide, such as a carbonate, nitrate, hydroxide, organic metallic compound and the like and mixtures thereof. The dielectric material is normally used in the form of a powder whose average particle diameter is about 0.1  $\mu\text{m}$  to about 3.0  $\mu\text{m}$ .  
10       The particle diameter of the dielectric raw material is preferably smaller than the thickness of the ceramic green sheet.

[0034]

          The amounts of the respective constituents contained in the dielectric paste is not particularly limited and the dielectric paste may be  
15       prepared so as to contain 100 weight parts of a dielectric material, about 2.5 weight part to about 10 weight parts of a butyral system resin and about 50 weight parts to about 320 weight parts of a solvent, for example.

[0035]

          As occasion demands, the dielectric paste may contain additives  
20       selected from among various dispersing agents, plasticizing agents, accessory ingredient compounds, glass frits, insulating materials and the like. In the case of adding these additives to the dielectric paste, it is preferable to set the total content to be equal to or less than about 10 weight %.

25           [0036]

          As a support sheet coated with the dielectric paste, a polyethylene terephthalate film is employed, for example, and the surface of the support sheet may be coated with a silicon resin, an alkyd resin or the like

in order to improve the releasability thereof.

[0037]

The coating layer is then dried at a temperature of about 50 °C to about 100 °C for about 1 to about 20 minutes, whereby a ceramic green  
5 sheet is formed on the support sheet.

[0038]

In the present invention, the thickness of the ceramic green sheet after drying is preferably equal to or thinner than 3 μm and more preferably equal to or thinner than 1.5 μm.

10 [0039]

Next, a conductive paste for forming an electrode layer is printed on the ceramic green sheet formed on the long support sheet in a predetermined pattern using a screen printing machine, a gravure printing machine or the like.

15 [0040]

It is preferable to form the electrode layer so as to have a dry thickness of about 0.1 μm to about 5 μm and it is more preferable to form the electrode layer so as to have a dry thickness of about 0.1 μm to about 1.5 μm.

20 [0041]

The conductive paste usable for forming an electrode layer is prepared by kneading a conductive material containing any of various conductive metals or alloys, any of various oxides which will form a conductive material containing any of various conductive metals or alloys  
25 after baking, an organic metal compound, resinate or the like, and an organic vehicle prepared by dissolving an acrylic system resin in an organic solvent.

[0042]

In this embodiment, the conductive paste contains an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d- dihydrocarvyl acetate as a solvent.

[0043]

Since the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d-dihydrocarvyl acetate hardly dissolves a butyral resin contained in a ceramic green sheet as a binder, even in the case of printing the conductive paste on a very thin ceramic green sheet, thereby forming an electrode layer, it is possible to effectively prevent the binder contained in the ceramic green sheet from being dissolved by the solvent contained in the conductive paste. Therefore, it is possible to effectively prevent generation of pinholes and cracks in the ceramic green sheet even in the case where the ceramic green sheet is very thin.

[0044]

It is preferable for the weight-average molecular weight of an acrylic system resin contained in a conductive paste to be equal to or larger than 450,000 and equal to or smaller than 900,000 and in the case where an acrylic system resin whose weight-average molecular weight is equal to or larger than 450,000 and equal to or smaller than 900,000 is employed as a binder of a conductive paste, it is possible to prepare a conductive paste having a desired viscosity.

[0045]

It is preferable for the acid value of an acrylic system resin contained in a conductive paste to be equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g and in the case where an

acrylic system resin whose acid value is equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g is employed as a binder of a conductive paste, it is possible to prepare a conductive paste having a desired viscosity.

5 [0046]

As the conductive material used for preparing the conductive paste, Ni, Ni alloy or the mixture thereof is preferably used. The shape of the conductive material is not particularly limited. The conductive material particles may have a spherical shape or a scale-like shape, or the  
10 conductive material may contain spherical conductive material particles and scale-like conductive material particles. The average particle diameter of the conductive material is not particularly limited but a conductive material having an average particle diameter of about 0.1  $\mu\text{m}$  to about 2  $\mu\text{m}$  is normally used for preparing the electrode paste and the  
15 conductive material having an average particle diameter of about 0.2  $\mu\text{m}$  to about 1  $\mu\text{m}$  is preferably used for preparing the electrode paste.

[0047]

The conductive paste preferably contains the binder in an amount about 2.5 weight parts to about 20 weight parts with respect to 100  
20 weight parts of the conductive material.

[0048]

The content of the solvent is preferably about 20 weight % to about 55 weight % with respect to the weight of the conductive paste.

[0049]

25 In order to improve adhesion property, it is preferable for the conductive paste to contain a plasticizing agent. The plasticizing agent contained in the conductive paste is not particularly limited and illustrative examples thereof include phthalate ester, adipic acid,



phosphate ester, glycols and the like. The conductive paste contains the plasticizing agent preferably in an amount of about 10 weight % to about 300 weight % with respect to 100 weight parts of the binder, more preferably in an amount of about 10 weight parts to about 200 weight parts. In the case where the amount of the plasticizing agent added to the conductive paste is too large, the strength of the electrode layer tends to be markedly lower.

[0050]

As occasion demands, the conductive paste may contain additives selected from among various dispersing agents accessory ingredient compounds and the like.

[0051]

Prior to forming an electrode layer or after forming an electrode layer and drying it, a dielectric paste adapted for forming a spacer layer and containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d-dihydrocarvyl acetate as a solvent is printed on the surface of a ceramic green sheet in a complementary pattern to that of the electrode layer using a screen printing machine, a gravure printing machine or the like, thereby forming a spacer layer.

[0052]

In the case where a spacer layer is formed on the surface of a ceramic green sheet in a complementary pattern to that of the electrode layer in this manner, it is possible to prevent a step from being formed between the surface of the electrode layer and the surface of the ceramic green sheet where no electrode layer is formed. Therefore, even in the case of laminating a number of multi-layered units each including a

ceramic green sheet and an electrode layer and fabricating a multi-layered electronic component such as a multi-layered ceramic capacitor, it is possible to effectively prevent the thus fabricated multi-layered electronic component from being deformed and also  
5 effectively prevent delamination of layers from occurring.

[0053]

Furthermore, as described above, since the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and  
10 d-dihydrocarvyl acetate hardly dissolves the butyral system resin contained in the ceramic green sheet as a binder, even in the case of printing the dielectric paste on a very thin ceramic green sheet, thereby forming a spacer layer, it is possible to reliably prevent the binder contained in the ceramic green sheet from being dissolved by the solvent  
15 contained in the dielectric paste, whereby the ceramic green sheet is swollen or partially dissolved so as to generate voids at the interface between the ceramic green sheet and the spacer layer or generate fissures or wrinkles on the surface of the spacer layer.

[0054]

20 In this embodiment, the dielectric paste for forming the spacer layer is prepared in the similar manner to the dielectric paste for forming the ceramic green sheet except that different binder and solvent are used.

[0055]

It is preferable for the weight-average molecular weight of an  
25 acrylic system resin contained in a dielectric paste for forming a spacer layer to be equal to or larger than 450,000 and equal to or smaller than 900,000 and in the case where an acrylic system resin whose weight-average molecular weight is equal to or larger than 450,000 and

equal to or smaller than 900,000 is employed as a binder of a dielectric paste for forming a spacer layer, it is possible to prepare a dielectric paste having a desired viscosity.

[0056]

5           It is preferable for the acid value of an acrylic system resin to be equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g and in the case where an acrylic system resin whose acid value is equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g is employed as a binder of a dielectric paste for forming a  
10 spacer layer, it is possible to prepare a dielectric paste having a desired viscosity.

[0057]

Then, the electrode layer or the electrode layer and the spacer layer are dried and a multi-layered unit including the ceramic green sheet  
15 and electrode layer or the electrode layer and the spacer layer laminated on the support sheet is fabricated.

[0058]

When a multi-layered ceramic capacitor is to be fabricated, the support sheet is peeled off from the ceramic green sheet of the  
20 multi-layered unit and the multi-layered unit is diced to predetermined dimensions. Then, a predetermined number of the multi-layered units are laminated on the outer layer of a multi-layered ceramic capacitor and the other outer layer of a multi-layered ceramic capacitor is further laminated on the multi-layered units, thereby fabricating a laminated  
25 body. Next, the thus obtained laminated body is press molded and diced to predetermined dimensions, thereby fabricating ceramic green chips.

[0059]

The thus fabricated ceramic green chips are placed in a reducing

gas atmosphere so that the binder is removed therefrom and the ceramic green chips are baked.

[0060]

Necessary external electrodes are then attached to the thus baked  
5 ceramic green chip, thereby manufacturing a multi-layered ceramic capacitor.

[0061]

According to this embodiment, since the spacer layer is formed on the surface of the ceramic green sheet in a complementary pattern to that  
10 of the electrode layer, it is possible to prevent a step from being formed between the surface of the electrode layer and the surface of the ceramic green sheet where no electrode layer is formed. Therefore, even in the case of laminating a number of multi-layered units each including a ceramic green sheet and an electrode layer and fabricating a  
15 multi-layered electronic component such as a multi-layered ceramic capacitor, it is possible to effectively prevent the thus fabricated multi-layered electronic component from being deformed and also effectively prevent delamination of layers from occurring.

[0062]

20 Further, according to this embodiment, the spacer layer is formed by printing the dielectric paste containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate as a  
25 solvent on the ceramic green sheet containing a butyral system resin as a binder in a predetermined pattern and the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl

acetate hardly dissolves a butyral system resin contained in a ceramic green sheet as a binder. As a result, even in the case of printing the dielectric paste on a very thin ceramic green sheet, thereby forming a spacer layer, it is possible to reliably prevent the binder contained in the ceramic green sheet from being dissolved by the solvent contained in the dielectric paste and the ceramic green sheet from being swollen or partially dissolved so as to generate voids at the interface between the ceramic green sheet and the spacer layer or generate fissures or wrinkles on the surface of the spacer layer. Therefore, in the case where a multi-layered ceramic capacitor is fabricated by laminating a number of multi-layered units each including a ceramic green sheet and an electrode layer, it is possible to reliably prevent voids from being generated in the multi-layered ceramic capacitor and it is also possible to reliably prevent the portions of the spacer layer where fissures or wrinkles are generated from dropping off during lamination of a number of the multi-layered units to fabricate the laminated body and mixing into the laminated body as a foreign substance so as to cause internal defects in the multi-layered ceramic capacitor.

[0063]

Furthermore, according to this embodiment, the electrode is formed by printing the conductive paste containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d-dihydrocarvyl acetate as a solvent on the ceramic green sheet containing a butyral system resin as a binder in a predetermined pattern and the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, I-dihydrocarvyl acetate, I-menthone, I-perillyl acetate, I-carvyl acetate, and d-dihydrocarvyl

I-citronellol, I-perillyl alcohol and acetoxy-methoxyethoxy-cyclohexanol acetate as a solvent on the ceramic green sheet containing an acrylic system resin as a binder in a predetermined pattern and the solvent selected from the group consisting of dihydroterpinyl oxyethanol, terpinyl oxyethanol, d-dihydrocarveol, I-citronellol, I-perillyl alcohol and acetoxy-methoxyethoxy-cyclohexanol acetate hardly dissolves an acrylic system resin contained in a ceramic green sheet as a binder. As a result, even in the case of printing the conductive paste on a very thin ceramic green sheet, thereby forming an electrode layer, it is possible to effectively prevent the binder contained in the ceramic green sheet from being dissolved by the solvent contained in the conductive paste. Therefore, even in the case where the ceramic green sheet is very thin, it is possible to effectively prevent generation of pinholes and cracks in a ceramic green sheet, thereby effectively preventing short circuit failure from occurring in a multi-layered ceramic electronic component.

[0063]

In another preferred embodiment of the present invention, a second support sheet is provided separately from the long support sheet used for forming the ceramic green sheet and the surface of the long second support sheet is coated using a wire bar coater or the like with a dielectric paste containing particles of a dielectric material having substantially the same composition as that of the dielectric material contained in the ceramic green sheet and the same binder as that contained in the ceramic green sheet, thereby forming a coating layer and the coating layer is dried to form a release layer.

[0064]

As the second support sheet, a polyethylene terephthalate film is employed, for example, and the surface of the second support sheet may

about 60 % of the electrode layer thickness and most preferably equal to or thinner than about 30 % of the electrode layer thickness.

[0067]

After the release layer has been dried, the conductive paste for an electrode layer prepared in the above described manner is printed on the surface of the release layer in a predetermined pattern using a screen printing machine, a gravure printing machine or the like, thereby forming an electrode layer.

[0068]

It is preferable to form the electrode layer so as to have a thickness of about 0.1  $\mu\text{m}$  to about 5  $\mu\text{m}$  and it is more preferable to form the electrode layer so as to have a thickness of about 0.1  $\mu\text{m}$  to about 1.5  $\mu\text{m}$ .

[0069]

In this embodiment, the conductive paste contains an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate as a solvent.

[0070]

Since a solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate hardly dissolves a butyral system resin contained in a ceramic green sheet as a binder, even in the case of forming a release layer containing the same binder as that of the ceramic green sheet and printing the conductive paste on the release layer to form an electrode layer, it is possible to effectively prevent the release layer from being swollen or partially dissolved so as to generate voids at the interface between the release layer and the electrode layer or

generate fissures or wrinkles on the surface of the electrode layer.

[0071]

It is preferable for the weight-average molecular weight of an acrylic system resin contained in a conductive paste to be equal to or larger than 450,000 and equal to or smaller than 900,000 and in the case where an acrylic system resin whose weight-average molecular weight is equal to or larger than 450,000 and equal to or smaller than 900,000 is employed as a binder of a conductive paste, it is possible to prepare a conductive paste having a desired viscosity.

10 [0072]

It is preferable for the acid value of an acrylic system resin contained in a conductive paste to be equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g and in the case where an acrylic system resin whose acid value is equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g is employed as a binder of a conductive paste, it is possible to prepare a conductive paste having a desired viscosity.

[0073]

Prior to forming an electrode layer or after forming an electrode layer and drying it, a dielectric paste containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate as a solvent and prepared in the above described manner is printed on the surface of the second support sheet in a complementary pattern to that of the electrode layer using a screen printing machine, a gravure printing machine or the like, thereby forming a spacer layer.

25 [0074]



In the case where the spacer layer is formed on the surface of a ceramic green sheet in a complementary pattern to that of the electrode layer in this manner, it is possible to prevent a step from being formed between the surface of the electrode layer and the surface of the ceramic green sheet where no electrode layer is formed. Therefore, even in the case of laminating a number of multi-layered units each including a ceramic green sheet and an electrode layer and fabricating a multi-layered electronic component such as a multi-layered ceramic capacitor, it is possible to effectively prevent the thus fabricated multi-layered electronic component from being deformed and also effectively prevent delamination of layers from occurring.

[0075]

Further, as described above, since the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate hardly dissolves a butyral system resin contained in the ceramic green sheet as a binder, even in the case of forming the release layer containing the same binder as that of the ceramic green sheet and printing a dielectric paste on the release layer to form a spacer layer, it is possible to effectively prevent the release layer from being swollen or partially dissolved so as to generate voids at the interface between the release layer and the spacer layer or generate fissures or wrinkles on the surface of the spacer layer.

[0076]

It is preferable for the weight-average molecular weight of an acrylic system resin contained in a dielectric paste for forming a spacer layer to be equal to or larger than 450,000 and equal to or smaller than 900,000 and in the case where an acrylic system resin whose

weight-average molecular weight is equal to or larger than 450,000 and equal to or smaller than 900,000 is employed as a binder of a dielectric paste for forming a spacer layer, it is possible to prepare a dielectric paste having a desired viscosity.

5 [0077]

It is preferable for the acid value of an acrylic system resin to be equal to or larger than 5 mgKOH/g and equal to or smaller than 25 mgKOH/g and in the case where an acrylic system resin whose acid value is equal to or larger than 5 mgKOH/g and equal to or smaller than 25  
10 mgKOH/g is employed as a binder of a dielectric paste for forming a spacer layer, it is possible to prepare a dielectric paste having a desired viscosity.

[0078]

Further, a long third support sheet is provided and the surface of  
15 the third support sheet is coated with an adhesive agent solution using a bar coater, an extrusion coater, a reverse coater, a dip coater, a kiss coater or the like and the coating layer is dried, thereby forming an adhesive layer.

[0079]

It is preferable for the adhesive agent solution to contain a binder  
20 belonging to the same group as that the binder contained in the ceramic green sheet belongs to, particles of a dielectric material having substantially the same composition as that of dielectric particles contained in the ceramic green sheet, a plasticizing agent, an antistatic  
25 agent and a release agent.

[0080]

It is preferable to form an adhesive layer so as to have a thickness thinner than about 0.3  $\mu\text{m}$ , more preferable to form it so as to have a

thickness of about 0.02  $\mu\text{m}$  to about 0.3  $\mu\text{m}$  and particularly preferable to form it so as to have a thickness of about 0.02  $\mu\text{m}$  to about 0.2  $\mu\text{m}$ .

[0081]

The adhesive layer formed on the long third support sheet in this manner is bonded onto the surfaces of the electrode layer and the spacer layer formed on the long second support sheet or the surface of the ceramic green sheet formed on the support sheet and the third support sheet then is peeled off from the adhesive layer, whereby the adhesive layer is transferred onto the surface of the electrode layer or the surfaces of the electrode layer and the spacer layer or the surface of the ceramic green sheet.

[0082]

In the case where the adhesive layer is transferred onto the surfaces of the electrode layer and the spacer layer, the ceramic green sheet formed on the long support sheet is bonded onto the adhesive layer and the support sheet is peeled off from the ceramic green sheet so that the ceramic green sheet is transferred onto the surface of the adhesive layer, thereby fabricating a multi-layered unit including the ceramic green sheet and the electrode layer.

[0083]

An adhesive layer is transferred onto the surface of the ceramic green sheet of the thus fabricated multi-layered unit in a similar manner to that of transferring the adhesive layer onto the surfaces of the electrode layer and the spacer layer and the multi-layered unit including the adhesive layer transferred onto the surface thereof is diced to predetermined dimensions.

[0084]

Similarly, a predetermined number of multi-layered units each

including the adhesive layer transferred onto the surface thereof are fabricated and the predetermined number of multi-layered units are laminated, thereby fabricating a multi-layered block.

[0085]

5           When a multi-layered block is to be fabricated, the multi-layered unit is first positioned on a support formed of polyethylene terephthalate or the like in such a manner that the adhesive layer transferred onto the surface of the multi-layered unit comes into contact with the support and the multi-layered unit is pressed by a pressing machine or the like,  
10       whereby the multi-layered unit is bonded onto the support via the adhesive layer.

[0086]

Afterwards, the second support sheet is peeled off from the release layer and the multi-layered unit is laminated on the support.

15           [0087]

Then, a new multi-layered unit is positioned on the surface of the release layer of the multi-layered unit laminated on the support in such a manner that an adhesive layer formed on the new multi-layered unit comes into contact with the surface of the release layer and the  
20       multi-layered unit is pressed using a pressing machine or the like, whereby the new multi-layered unit is laminated on the surface of the release layer of the multi-layered unit laminated on the support via the adhesive layer. Afterwards, the second support sheet is peeled off from the release layer of the new multi-layered unit.

25           [0088]

Similar processes are repeated, thereby fabricating a multi-layered block including a predetermined number of the laminated multi-layered units.

[0089]

On the other hand, in the case where the adhesive layer is transferred onto the surface of the ceramic green sheet, the electrode layer and the spacer layer formed on the second support sheet are bonded  
5 onto the adhesive layer and then, the second support sheet is peeled off from the release layer, the electrode layer and the spacer layer and the release layer are transferred onto the surface of the adhesive layer. Thus, a multi-layered unit including the ceramic green sheet and the electrode layer is fabricated.

10 [0090]

An adhesive layer is transferred onto the surface of the release layer of the thus obtained multi-layered unit in a similar manner to that of transferring the adhesive layer onto the surface of the ceramic green sheet and the multi-layered unit including the adhesive layer transferred  
15 onto the surface thereof is diced to predetermined dimensions.

[0091]

Similarly, a predetermined number of multi-layered units each including the adhesive layer transferred onto the surface thereof are fabricated and the predetermined number of multi-layered units are  
20 laminated, thereby fabricating a multi-layered block.

[0092]

When a multi-layered block is to be fabricated, the multi-layered unit is first positioned on a support formed of polyethylene terephthalate or the like in such a manner that the adhesive layer transferred onto the  
25 surface of the multi-layered unit comes into contact with the support and the multi-layered unit is pressed by a pressing machine or the like, whereby the multi-layered unit is bonded onto the support via the adhesive layer.

[0093]

Afterwards, the support sheet is peeled off from the ceramic green sheet and the multi-layered unit is laminated on the support.

[0094]

5           Then, a new multi-layered unit is positioned on the surface of the ceramic green sheet of the multi-layered unit laminated on the support in such a manner that an adhesive layer formed on the new multi-layered unit comes into contact with the surface of the ceramic green sheet and the multi-layered unit is pressed using a pressing machine or the like,  
10       whereby the new multi-layered unit is laminated on the surface of the ceramic green sheet of the multi-layered unit laminated on the support via the adhesive layer. Afterwards, the support sheet is peeled off from the release layer of the new multi-layered unit.

[0095]

15           Similar processes are repeated, thereby fabricating a multi-layered block including a predetermined number of the laminated multi-layered units.

[0096]

20           The thus fabricated multi-layered block including the predetermined number of the laminated multi-layered units is laminated on the outer layer of a multi-layered ceramic capacitor and the other outer layer of a multi-layered ceramic capacitor is further laminated on the multi-layered block, thereby fabricating a laminated body. Next, the thus obtained laminated body is press molded and diced to predetermined  
25       dimensions, thereby fabricating a number of ceramic green chips.

[0097]

The thus fabricated ceramic green chips are placed in a reducing gas atmosphere so that the binder is removed therefrom and the ceramic

green chips are baked.

[0098]

Necessary external electrodes are then attached to the thus baked ceramic green chip, thereby manufacturing a multi-layered ceramic capacitor.

[0099]

According to this preferred embodiment, since the spacer layer is formed using the dielectric paste containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate as a solvent and the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate hardly dissolves a butyral system resin contained in a ceramic green sheet as a binder. As a result, even in the case of forming the release layer containing the same binder as that contained in a ceramic green sheet and printing the dielectric paste on the release layer, thereby forming a spacer layer, it is possible to effectively prevent the release layer from being swollen or partially dissolved so as to generate voids at the interface between the release layer and the spacer layer or generate fissures or wrinkles on the surface of the spacer layer. Therefore, in the case where a multi-layered ceramic capacitor is fabricated by laminating a number of multi-layered units each including a ceramic green sheet and an electrode layer, it is possible to reliably prevent voids from being generated in the multi-layered ceramic capacitor and it is also possible to reliably prevent the portions of the spacer layer where fissures or wrinkles are generated from dropping off during lamination of a number of the multi-layered units to fabricate

the laminated body and mixing into the laminated body as a foreign substance so as to cause internal defects in the multi-layered ceramic capacitor.

[0100]

5 Further, according to this preferred embodiment, since the electrode layer and the spacer layer formed on the second support sheet are dried and then bonded onto the surface of the ceramic green sheet via the adhesive layer, unlike in the case of printing a conductive paste on the surface of the ceramic green sheet to form an electrode layer and printing  
10 a dielectric paste on the surface of the ceramic green sheet to form a spacer layer, it is possible to prevent the conductive paste and the dielectric paste from permeating into the ceramic green sheet and it is therefore possible to laminate the electrode layer and the spacer layer on the surface of the ceramic green sheet in a desired manner.

15 [0101]

Furthermore, according to this preferred embodiment, the electrode layer is formed using the conductive paste containing an acrylic system resin as a binder and at least one solvent selected from a group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate,  
20 l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate as a solvent and the solvent selected from the group consisting of limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate, and d-dihydrocarvyl acetate hardly dissolves a butyral system resin contained in a ceramic green sheet as a  
25 binder. Therefore, even in the case of forming a release layer containing the same binder as that contained in the ceramic green sheet and printing a conductive paste on the release layer to form an electrode layer, it is possible to effectively prevent generation of pinholes and cracks in the



release layer and effectively prevent generation of defects in a multi-layered ceramic electronic component such as a multi-layered ceramic capacitor.

[0102]

5           In a further preferred embodiment, in the case where the adhesive layer is transferred onto the surfaces of the electrode layer and the spacer layer, an adhesive layer is transferred onto the surface of a ceramic green sheet of a multi-layered unit fabricated by laminating a release layer, an electrode layer and a spacer layer, an adhesive layer and a ceramic green  
10 sheet on a long second support sheet and without cutting the multi-layered unit, a release layer of another multi-layered unit fabricated by laminating a ceramic green sheet, an adhesive layer, an electrode layer and a spacer layer, and the release layer on a long support sheet is bonded onto the adhesive layer and the support sheet is peeled off  
15 from the ceramic green sheet, whereby two multi-layered units are laminated on the long second support sheet.

[0103]

Then, an adhesive layer formed on a third support sheet is transferred onto the ceramic green sheet located on the side of the surface  
20 of the laminated two multi-layered units and a release layer of another multi-layered unit fabricated by laminating a ceramic green sheet, an adhesive layer, an electrode layer and a spacer layer, and the release layer on a long support sheet is bonded onto the adhesive layer and the support sheet is peeled off from the release layer.

25           [0104]

Similar processes are repeated, thereby fabricating a multi-layered unit set including a predetermined number of laminated multi-layered units. Further, an adhesive layer formed on the third

support sheet is transferred onto the surface of the ceramic green sheet located on the side of the surface of the multi-layered unit set, thereby fabricating a laminated body and the laminated body is diced to predetermined dimensions, thereby fabricating a multi-layered blocks.

5           [0105]

On the other hand, in the case where the adhesive layer is transferred onto the surface of the ceramic green sheet, an adhesive layer is transferred onto the surface of a release layer of a multi-layered unit fabricated by laminating a ceramic green sheet, an adhesive layer, an electrode layer and a spacer layer, and the release layer on a long support sheet and without cutting the multi-layered unit, a ceramic green sheet of another multi-layered unit fabricated by laminating a release layer, an electrode layer and a spacer layer, an adhesive layer and a ceramic green sheet on a long second support sheet is bonded onto the adhesive layer and the second support sheet is peeled off from the release layer, whereby two multi-layered units are laminated on the long second support sheet.

          [0106]

Then, an adhesive layer formed on a third support sheet is transferred onto the release layer located on the side of the surface of the laminated two multi-layered units and a ceramic green sheet of a multi-layered unit fabricated by laminating a release layer, an electrode layer and a spacer layer, an adhesive layer and a ceramic green sheet on a long second support sheet is further laminated on the adhesive layer. Then, the second support sheet is peeled off from the release layer.

25          [0107]

Similar processes are repeated, thereby fabricating a multi-layered unit set including a predetermined number of laminated multi-layered units. Further, an adhesive layer formed on the third

support sheet is transferred onto the surface of the release layer located on the side of the surface of the multi-layered unit set, thereby fabricating a laminated body and the laminated body is diced to predetermined dimensions, thereby fabricating multi-layered blocks.

5 [0108]

A multi-layered ceramic capacitor is fabricated using the thus fabricated multi-layered blocks in the manner of the previous preferred embodiment.

[0109]

10 According to this preferred embodiment, since the multi-layered units are successively laminated on the long second support sheet or support sheet, thereby fabricating the multi-layered unit set including a predetermined number of multi-layered units and the multi-layered unit set is diced to predetermined dimensions, thereby fabricating  
15 multi-layered blocks, it is possible to markedly improve the manufacturing efficiency of the multi-layered blocks in comparison with the case where multi-layered blocks are fabricated by laminating multi-layered units each of which has been diced to predetermined dimensions.

20 [0110]

In a further preferred embodiment of the present invention, in the case where the adhesive layer is transferred onto the surfaces of the electrode layer and the spacer layer, an adhesive layer is transferred onto the surface of a ceramic green sheet of a multi-layered unit fabricated by  
25 laminating a release layer, an electrode layer and a spacer layer, an adhesive layer and a ceramic green sheet on a long second support sheet and without cutting the multi-layered unit, an electrode layer and a spacer layer formed on the second support sheet are bonded onto the

adhesive layer and the second support sheet is peeled off from the release layer, whereby the electrode layer and the spacer layer, and the release layer are transferred onto the surface of the adhesive layer.

[0111]

5        Then, an adhesive layer formed on a third support sheet is transferred onto the surface of the release layer transferred onto the adhesive layer, a ceramic green sheet formed on the support sheet is bonded onto the adhesive layer and the support sheet is peeled off from the ceramic green sheet, whereby the ceramic green sheet is transferred  
10       onto the surface of the adhesive layer.

[0112]

Further, an adhesive layer formed on a third support sheet is transferred onto the surface of the ceramic green sheet transferred onto the surface of the adhesive layer, an electrode layer and a spacer layer  
15       formed on the second support sheet are bonded onto the adhesive layer and the second support sheet is peeled off from the release layer, whereby the electrode layer and the spacer layer, and the release layer are transferred onto the surface of the adhesive layer.

[0113]

20       Similar processes are repeated, thereby fabricating a multi-layered unit set including a predetermined number of laminated multi-layered units. Further, an adhesive layer formed on the third support sheet is transferred onto the surface of the ceramic green sheet located on the side of the surface of the multi-layered unit set, thereby  
25       fabricating a laminated body and the laminated body is diced to predetermined dimensions, thereby fabricating multi-layered blocks.

[0114]

On the other hand, in the case where the adhesive layer is

transferred onto the surface of the ceramic green sheet, an adhesive layer is transferred onto the surface of a release layer of a multi-layered unit fabricated by laminating a ceramic green sheet, an adhesive layer, an electrode layer and a spacer layer, and the release layer on a long support sheet and without cutting the multi-layered unit, a ceramic green sheet of  
5 a support sheet is bonded onto the adhesive layer and the support sheet is peeled off from the ceramic green sheet, whereby the ceramic green sheet is transferred onto the adhesive layer.

[0115]

10 Further, an adhesive layer formed on the third support sheet is transferred onto the ceramic green sheet transferred onto the adhesive layer and an electrode layer and a spacer layer formed on the second support sheet is bonded onto the adhesive layer. Then, the second support sheet is peeled off from the release layer, whereby the electrode layer and  
15 the spacer layer, and the release layer are transferred onto the surface of the adhesive layer.

[0116]

Further, an adhesive layer formed on the third support sheet is transferred onto the release layer transferred onto the adhesive layer and  
20 a ceramic green sheet formed on the support sheet is bonded onto the adhesive layer. Then, the support sheet is peeled off from the ceramic green sheet, whereby the ceramic green sheet is transferred onto the surface of the adhesive layer.

[0117]

25 Similar processes are repeated, thereby fabricating a multi-layered unit set including a predetermined number of laminated multi-layered units. Further, an adhesive layer is transferred onto the surface of the release layer located on the side of the surface of the

multi-layered unit set, thereby fabricating a laminated body and the laminated body is diced to predetermined dimensions, thereby fabricating multi-layered blocks.

[0118]

5        A multi-layered ceramic green sheet is fabricated using the thus fabricated multi-layered block in the manner of the previous embodiment.

[0119]

      According to this preferred embodiment, the transferring of the adhesive layer, the transferring of the electrode layer and the spacer layer  
10    and the release layer, the transferring of the adhesive layer and the transferring of the ceramic green sheet onto the long second support sheet or support sheet are repeated, thereby successively laminating the multi-layered units to fabricate the multi-layered unit set including a predetermined number of multi-layered units and the multi-layered unit.  
15    set is diced to predetermined dimensions, thereby fabricating multi-layered blocks. As a result, it is possible to markedly improve the manufacturing efficiency of the multi-layered block in comparison with the case where multi-layered blocks are fabricated by laminating multi-layered units each of which has been diced to predetermined  
20    dimensions.

## **[WORKING EXAMPLES]**

[0120]

      Hereinafter, working examples and comparative examples will be  
25    set out in order to further clarify the advantages of the present invention.

[0121]

### **Working Example 1**

#### **Preparation of a dielectric paste for forming a ceramic green sheet**

1.48 weight parts of  $(\text{BaCa})\text{SiO}_3$ , 1.01 weight parts of  $\text{Y}_2\text{O}_3$ , 0.72 weight part of  $\text{MgCO}_3$ , 0.13 weight part of  $\text{MnO}$  and 0.045 weight part of  $\text{V}_2\text{O}_5$  were mixed, thereby preparing an additive powder.

[0122]

5         72.3 weight parts of ethyl alcohol, 72.3 weight parts of propyl alcohol, 25.8 weight parts of xylene and 0.93 weight parts of polyethyleneglycol system dispersing agent were added to 100 weight parts of the thus prepared additive powder to prepare a slurry and the additives contained in the slurry were pulverized.

10         [0123]

When the additives contained in the slurry were to be pulverized, 11.65 grams of the slurry and 450 grams of  $\text{ZrO}_2$  beads having a diameter of 2 mm were charged in a polyethylene vessel having an inner volume of 250 cc and the polyethylene vessel was rotated at the circumferential  
15         velocity of 45 m/min for sixteen hours, thereby pulverizing the additive powder to prepare the additive slurry.

[0124]

The median diameter of the additives after pulverization was 0.1  $\mu\text{m}$ .

20         [0125]

Then, 15 weight parts of polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % was dissolved into a mixture of 42.5 weight parts of ethyl alcohol and 42.5 weight parts of propyl alcohol at 50 °C, thereby preparing a 15 % organic  
25         vehicle solution. Further, a slurry having the composition set out below was mixed with the organic vehicle solution for twenty hours using a ball mill having an inner volume of 500 cc, thereby preparing a dielectric paste. When the slurry was to be mixed with the organic vehicle solution,

330.1 grams of the slurry and 900 grams of ZrO<sub>2</sub> beads having a diameter of 2 mm were charged in the polyethylene vessel and the polyethylene vessel was rotated at the circumferential velocity of 45 m/min.

[0126]

5	BaTiO <sub>3</sub> powders ("BT-02" (Product Name) manufactured by SAKAI CHEMICAL INDUSTRY CO., LTD.: particle diameter 0.2 μm)	100 weight parts
	additive slurry	11.65 weight parts
	ethyl alcohol	35.32 weight parts
10	propyl alcohol	35.32 weight parts
	xylene	16.32 weight parts
	benzyl butyl phthalate (plasticizing agent)	2.61 weight parts
	mineral sprit	7.3 weight parts
	polyethylene glycol system dispersing agent	2.36 weight parts
15	imidazoline system antistatic auxiliary agent	0.42 weight parts
	organic vehicle	33.74 weight parts
	methyl ethyl ketone	43.81 weight parts
	2-butoxyethyl alcohol	43.81 weight parts

20 As a polyethylene glycol system dispersing agent, a dispersing agent which was obtained by denaturing polyethylene glycol with aliphatic acid and whose hydrophile-liophile balance (HLB) was 5 to 6 was employed.

[0127]

25 Formation of a ceramic green sheet

A polyethylene terephthalate film was coated with the thus prepared dielectric paste using a die coater at a coating velocity of 50 m/minutes, thereby forming a coating layer and the thus formed coating



layer was dried in a drying furnace whose temperature was held at 80 °C, thereby forming a ceramic green sheet having a thickness of 1 μm.

[0128]

Preparation of a dielectric paste for forming a spacer layer

5           1.48 weight parts of (BaCa)SiO<sub>3</sub>, 1.01 weight parts of Y<sub>2</sub>O<sub>3</sub>, 0.72 weight part of MgCO<sub>3</sub>, 0.13 weight part of MnO and 0.045 weight part of V<sub>2</sub>O<sub>5</sub> were mixed, thereby preparing an additive powder.

[0129]

150 weight parts of acetone, 104.3 weight parts of limonene and  
10 1.5 weight parts of polyethylene glycol system dispersing agent were added to 100 weight parts of the thus prepared additive powder to prepare a slurry and the additives contained in the slurry were pulverized using a pulverizer "LMZ0.6" (Product name) manufactured by Ashizawa Finetech Co., Ltd.

15           [0130]

When the additives contained in the slurry were to be pulverized, ZrO<sub>2</sub> beads having a diameter of 0.1 mm were charged into a vessel so as to occupy 80 volume % of the vessel, a rotor was rotated at the circumferential velocity of 14 m/min and the slurry was circulated  
20 between the vessel and a slurry tank until holding time of the whole slurry became 30 minutes, thereby pulverizing the additives contained in the slurry.

[0131]

The median diameter of the additives after pulverization was 0.1  
25 μm.

[0132]

Then, acetone was evaporated using an evaporator and removed from the slurry, thereby preparing an additive paste in which the

additives were dispersed in limonene. The concentration of the additives contained in the additive paste was 49.3 weight %.

[0133]

Further, 8 weight parts of a copolymer of methyl methacrylate and butyl acrylate whose acid value was 5 mgKOH/gram, copolymerization ratio (weight ratio) was 82:18 and weight-average molecular weight was 700,000 was dissolved into 92 weight parts of limonene at 70 °C, thereby preparing an organic vehicle solution of 8 %. Furthermore, a slurry having the composition set out below was dispersed in the organic vehicle solution for sixteen hours using a ball mill. The dispersing conditions were set so that the amount of charged ZrO<sub>2</sub> having a diameter of 2.0 mm was 30 volume % of the ball mill, the amount of the slurry in the ball mill was 60 volume % and the circumferential velocity of the ball mill was 45 m/min.

[0134]

additive paste	8.87 weight parts
BaTiO <sub>3</sub> powder ("BT-02" (Product Name) manufactured by SAKAI CHEMICAL INDUSTRY CO., LTD.: particle diameter 0.2 μm)	
	95.70 weight parts
organic vehicle	104.36 weight parts
polyethylene glycol system dispersing agent	1.19 weight parts
dioctyl phthalate (plasticizing agent)	2.61 weight parts
imidazoline system surfactant	0.4 weight parts
acetone	57.20 weight parts

Then, acetone was evaporated using a stirring device having an evaporator and a heating mechanism and removed from the slurry, thereby preparing a dielectric paste.

[0135]

Formation of a spacer layer

The thus prepared dielectric paste was printed on the surface of the ceramic green sheet in a predetermined pattern using a screen printing machine and dried at 90 °C for five minutes, thereby forming a spacer layer on the surface of the ceramic green sheet.

[0136]

Further, the surface of the spacer layer was observed at four-hundred magnifications using a metallographic microscope. As a result, it was found that the surface of the spacer layer was free of cracks and wrinkles.

[0137]

Preparation of a conductive paste for forming an electrode layer

1.48 weight parts of (BaCa)SiO<sub>3</sub>, 1.01 weight parts of Y<sub>2</sub>O<sub>3</sub>, 0.72 weight part of MgCO<sub>3</sub>, 0.13 weight part of MnO and 0.045 weight part of V<sub>2</sub>O<sub>5</sub> were mixed, thereby preparing an additive powder.

[0138]

150 weight parts of acetone, 104.3 weight parts of limonene and 1.5 weight parts of polyethylene glycol system dispersing agent were added to 100 weight parts of the thus prepared additive powder to prepare a slurry and the additives contained in the slurry were pulverized using a pulverizer "LMZ0.6" (Product name) manufactured by Ashizawa Finetech Co., Ltd.

[0139]

When the additives contained in the slurry were to be pulverized, ZrO<sub>2</sub> beads having a diameter of 0.1 mm were charged into a vessel so as to occupy 80 volume % of the vessel, a rotor was rotated at the circumferential velocity of 14 m/min and the slurry was circulated



LTD.	19.14 weight parts
organic vehicle	56.25 weight parts
polyethylene glycol system dispersing agent	1.19 weight parts
dioctyl phthalate (plasticizing agent)	2.25 weight parts
5 limonene	83.96 weight parts
acetone	56 weight parts

Then, acetone was evaporated using a stirring device having an evaporator and a heating mechanism and removed from the slurry, thereby preparing a conductive paste. The concentration of the dielectric material contained in the conductive paste was 47 weight %.

[0144]

#### Formation of an electrode layer and fabrication of a multi-layered unit

The thus prepared conductive paste was printed on the ceramic green sheet in a complimentary pattern to that of the spacer layer using a screen printing machine and dried at 90 °C for five minutes, thereby forming an electrode layer having a thickness of 1 μm. Thus, a multi-layered unit including the ceramic green sheet, the electrode layer and the spacer layer laminated on the polyethylene terephthalate film was fabricated.

[0145]

Further, the surface of the electrode layer was observed at four-hundred magnifications using a metallographic microscope. As a result, it was found that the surface of the electrode layer was free of cracks and wrinkles.

[0146]

#### Fabrication of a ceramic green chip

The surface of a polyethylene terephthalate film was coated with

the dielectric paste prepared in the above described manner using a die coater, thereby forming a coating layer, and the coating layer was dried, thereby forming a ceramic green sheet having a thickness of 10  $\mu\text{m}$ .

[0147]

5       The thus formed ceramic green sheet was peeled off from the polyethylene terephthalate film and diced. Five of the diced ceramic green sheet units were laminated to form a cover layer having a thickness of 50  $\mu\text{m}$ . Further, the multi-layered unit was peeled off from the polyethylene terephthalate film and diced and fifty of the diced multi-layered units  
10       were laminated on the cover layer.

[0148]

Then, the ceramic green sheet having a thickness of 10  $\mu\text{m}$  was peeled off from the polyethylene terephthalate film and diced and five of the ceramic green sheet units were laminated on the multi-layered units  
15       laminated on the cover layer, thereby fabricating a laminated body including the lower cover layer having a thickness of 50  $\mu\text{m}$ , an active layer having a thickness of 100  $\mu\text{m}$  and including the laminated fifty multi-layered units each including the ceramic green sheet having a thickness of 1  $\mu\text{m}$ , the electrode layer having a thickness of 1  $\mu\text{m}$  and the  
20       spacer layer having a thickness of 1  $\mu\text{m}$ , and an upper cover layer having a thickness of 50  $\mu\text{m}$ .

[0149]

Further, a pressure of 100 MPa was applied onto the thus fabricated laminated body at 70  $^{\circ}\text{C}$ , thereby press molding the laminated  
25       body and the laminated body was diced to predetermined dimensions using a dicing machine, thereby fabricating ceramic green chips.

[0150]

A total of fifty ceramic green chips were fabricated in a manner

similar to the foregoing.

[0151]

Fabrication of a multi-layered ceramic capacitor sample

Each of the thus fabricated ceramic green chip was processed  
5 under the following conditions in an air atmosphere to remove the binder.

[0152]

Rate of temperature increase: 50 °C / hour

Holding temperature: 240 °C

Holding time period: 8 hours

10 After removing the binder, the ceramic green chip was processed  
and baked under the following conditions in a mixed gas atmosphere of a  
nitrogen gas and a hydrogen gas whose temperature was controlled at the  
dew point 20 °C. The contents of the nitrogen gas and the hydrogen gas  
contained in the mixed gas were 95 volume % and 5 volume %, respectively.  
15

[0153]

Rate of temperature increase: 300 °C / hour

Holding temperature: 1200 °C

Holding time period: 2 hours

20 Cooling rate: 300 °C / hour

The thus baked ceramic green chip was subjected to an annealing  
treatment under the following conditions in a nitrogen gas atmosphere  
whose temperature was controlled at the dew point 20 °C.

[0154]

25 Rate of temperature increase: 300 °C / hour

Holding temperature: 1000 °C

Holding time period: 3 hours

Cooling rate: 300 °C / hour

The ceramic green chip which had been subjected to an annealing treatment in this manner was embedded in a two liquid curable type epoxy resin so that the side surface was exposed to the outside and after the two liquid curable type epoxy resin was cured, the ceramic green chip  
5 was ground by 1.6 mm using # 400 sand paper, # 800 sand paper, # 1000 sand paper and # 2000 sand paper in this order.

[0155]

The thus ground surface of the ceramic green chip was subjected to a mirror polishing processing using 1  $\mu\text{m}$  diamond paste and the thus  
10 polished surface of the ceramic green chip was observed at four-hundred magnifications using an optical microscope to examine whether any void was present.

[0156]

As a result, no void was observed in any of fifty ceramic green  
15 chips.

[0157]

The end surfaces of each of the thus obtained sintered bodies were polished by the sandblast and coated with In-Ga alloy, thereby forming a terminal electrode. Thus, a multi-layered ceramic capacitor sample was  
20 fabricated.

[0158]

Similarly, a total of fifty multi-layered ceramic capacitor samples were fabricated.

[0159]

#### 25 Measurement of short-circuit failure ratio

The resistance value of each of the thus fabricated multi-layered ceramic capacitor samples was measured using a multi-meter to check whether or not short-circuit failure occurred therein.



[0160]

In the case where the thus measured resistance value was equal to or lower than 100 K $\Omega$ , it was judged that short-circuit failure occurred in the multi-layered ceramic capacitor sample. The number of the ceramic capacitor samples in which short-circuit failure occurred was measured and the ratio of the number of the ceramic capacitor samples in which short-circuit failure occurred to the total number of the fabricated multi-layered ceramic capacitor samples was calculated and defined as the short-circuit failure ratio.

[0161]

As a result, the short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 16 %.

[0162]

#### Working Example 2

An electrode layer and a spacer layer were formed on a ceramic green sheet in the manner of Working Example 1 except that  $\alpha$ -terpinyl acetate was used instead of limonene as the solvent for preparing the conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer. Then, the surfaces of the electrode layer and the spacer layer were observed at four-hundred magnifications using a metallographic microscope. As a result, it was found that the surfaces of the electrode layer and the spacer layer were free of cracks and wrinkles.

[0163]

Furthermore, fifty ceramic green chips were fabricated in the manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and an annealing treatment was polished and the thus polished surfaces of

the ceramic green chips were observed using an optical microscope. As a result, no void was observed in any of the ceramic green chips.

[0164]

Moreover, fifty multi-layered ceramic capacitor samples were  
5 fabricated in the manner of Working Example 1 and the resistance value  
of each of the thus fabricated multi-layered ceramic capacitor samples  
was measured using a multi-meter to determine the short-circuit failure  
ratio of the multi-layered ceramic capacitor samples. As a result, the  
short-circuit failure ratio of the multi-layered ceramic capacitor samples  
10 was found to be 14 %.

[0165]

### Working Example 3

An electrode layer and a spacer layer were formed on a ceramic  
green sheet in the manner of Working Example 1 except that  
15 I-dihydrocarvyl acetate was used instead of limonene as the solvent for  
preparing the conductive paste for forming the electrode layer and a  
solvent for preparing the dielectric paste for forming the spacer layer.  
Then, the surfaces of the electrode layer and the spacer layer were  
observed at four-hundred magnifications using a metallographic  
20 microscope. As a result, it was found that the surfaces of the electrode  
layer and the spacer layer were free of cracks and wrinkles.

[0166]

Furthermore, fifty ceramic green chips were fabricated in the  
manner of Working Example 1. Then, the side surface of each of the  
25 ceramic green chips which had been subjected to a baking treatment and  
an annealing treatment was polished and the thus polished surfaces of  
the ceramic green chips were observed using an optical microscope. As a  
result, no void was observed in any of the ceramic green chips.

[0167]

Moreover, fifty multi-layered ceramic capacitor samples were fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 18 %.

[0168]

#### 10 Working Example 4

An electrode layer and a spacer layer were formed on a ceramic green sheet in the manner of Working Example 1 except that I-menthone was used instead of limonene as the solvent for preparing the conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer. Then, the surfaces of the electrode layer and the spacer layer were observed at four-hundred magnifications using a metallographic microscope. As a result, it was found that the surfaces of the electrode layer and the spacer layer were free of cracks and wrinkles.

20 [0169]

Furthermore, fifty ceramic green chips were fabricated in the manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and an annealing treatment was polished and the thus polished surfaces of the ceramic green chips were observed using an optical microscope. As a result, no void was observed in any of the ceramic green chips.

[0170]

Moreover, fifty multi-layered ceramic capacitor samples were

fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the  
5 short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 10 %.

[0171]

#### Working Example 5

An electrode layer and a spacer layer were formed on a ceramic  
10 green sheet in the manner of Working Example 1 except that I-perillyl acetate was used instead of limonene as the solvent for preparing the conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer. Then, the surfaces of the electrode layer and the spacer layer were observed at  
15 four-hundred magnifications using a metallographic microscope. As a result, it was found that the surfaces of the electrode layer and the spacer layer were free of cracks and wrinkles.

[0172]

Furthermore, fifty ceramic green chips were fabricated in the  
20 manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and an annealing treatment was polished and the thus polished surfaces of the ceramic green chips were observed using an optical microscope. As a result, no void was observed in any of the ceramic green chips.

25 [0173]

Moreover, fifty multi-layered ceramic capacitor samples were fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples

was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 16 %.

5 [0174]

#### Working Example 6

An electrode layer and a spacer layer were formed on a ceramic green sheet in the manner of Working Example 1 except that I-carvyl acetate was used instead of limonene as the solvent for preparing the  
10 conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer. Then, the surfaces of the electrode layer and the spacer layer were observed at four-hundred magnifications using a metallographic microscope. As a result, it was found that the surfaces of the electrode layer and the spacer  
15 layer were free of cracks and wrinkles.

[0175]

Furthermore, fifty ceramic green chips were fabricated in the manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and  
20 an annealing treatment was polished and the thus polished surfaces of the ceramic green chips were observed using an optical microscope. As a result, no void was observed in any of the ceramic green chips.

[0176]

Moreover, fifty multi-layered ceramic capacitor samples were  
25 fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the

short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 8 %.

[0177]

#### Working Example 7

5       An electrode layer and a spacer layer were formed on a ceramic green sheet in the manner of Working Example 1 except that d-dihydrocarvyl acetate was used instead of limonene as the solvent for preparing the conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer.  
10   Then, the surfaces of the electrode layer and the spacer layer were observed at four-hundred magnifications using a metallographic microscope. As a result, it was found that the surfaces of the electrode layer and the spacer layer were free of cracks and wrinkles.

[0178]

15       Furthermore, fifty ceramic green chips were fabricated in the manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and an annealing treatment was polished and the thus polished surfaces of the ceramic green chips were observed using an optical microscope. As a  
20   result, no void was observed in any of the ceramic green chips.

[0179]

      Moreover, fifty multi-layered ceramic capacitor samples were fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples  
25   was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 10 %.

[0180]

#### Comparative Example 1

An electrode layer and a spacer layer were formed on a ceramic green sheet in the manner of Working Example 1 except that a mixed solvent of terpineol and kerosene (mixture ratio (mass ratio) of 50:50) was used instead of limonene as the solvent for preparing the conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer. Then, the surfaces of the electrode layer and the spacer layer were observed at four-hundred magnifications using a metallographic microscope. As a result, cracks and wrinkles were observed on the surface of the electrode layer.

[0181]

Furthermore, fifty ceramic green chips were fabricated in the manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and an annealing treatment was polished and the thus polished surfaces of the ceramic green chips were observed using an optical microscope. As a result, voids were observed in seventeen ceramic green chips among fifty ceramic green chips.

[0182]

Moreover, fifty multi-layered ceramic capacitor samples were fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 90 %.

[0183]

## Comparative Example 2

An electrode layer and a spacer layer were formed on a ceramic green sheet in the manner of Working Example 1 except that terpineol was used instead of limonene as the solvent for preparing the conductive paste for forming the electrode layer and a solvent for preparing the dielectric paste for forming the spacer layer. Then, the surfaces of the electrode layer and the spacer layer were observed at four-hundred magnifications using a metallographic microscope. As a result, cracks and wrinkles were observed on the surface of the electrode layer.

[0184]

Furthermore, fifty ceramic green chips were fabricated in the manner of Working Example 1. Then, the side surface of each of the ceramic green chips which had been subjected to a baking treatment and an annealing treatment was polished and the thus polished surfaces of the ceramic green chips were observed using an optical microscope. As a result, voids were observed in twenty three ceramic green chips among fifty ceramic green chips.

[0185]

Moreover, fifty multi-layered ceramic capacitor samples were fabricated in the manner of Working Example 1 and the resistance value of each of the thus fabricated multi-layered ceramic capacitor samples was measured using a multi-meter to determine the short-circuit failure ratio of the multi-layered ceramic capacitor samples. As a result, the short-circuit failure ratio of the multi-layered ceramic capacitor samples was found to be 88 %.

[0186]

It was found from Working Examples 1 to 7 and Comparative Examples 1 and 2 that in the case where the dielectric paste containing a



copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and the mixed solvent of terpeneol and kerosene (mixture ratio (mass ratio) of 50:50) as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and the mixed solvent of terpeneol and kerosene (mixture ratio (mass ratio) of 50:50) as a solvent was printed on surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, and in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and terpeneol as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and terpeneol as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, it was observed that cracks and wrinkles were generated on the surface of the spacer layer and the surface of the electrode layer and voids

were generated in the ceramic green chip after baking, while in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and limonene as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and limonene as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and  $\alpha$ -terpinyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and  $\alpha$ -terpinyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a

binder and I-dihydrocarvyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-dihydrocarvyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-menthone as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-menthone as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-perillyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of

polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-perillyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-carvyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-carvyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, and in the case where the dielectric paste containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and d-dihydrocarvyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the spacer layer and the conductive paste containing a copolymer of methyl methacrylate and butyl acrylate whose

weight-average molecular weight was 700,000 as a binder and d-dihydrocarvyl acetate as a solvent was printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby forming the electrode layer, it was found that the surface of the spacer layer and the surface of the electrode layer were free of cracks and wrinkles and that no void was generated in the ceramic green chip after baking.

[0187]

It is reasonable to assume that this was because the mixed solvent of terpineol and kerosene (mixture ratio (mass ratio) of 50:50) and terpineol used as the solvent of the dielectric paste for forming the spacer layer in Comparative Examples 1 and 2 dissolved polyvinyl butyral contained in the dielectric paste used for forming the ceramic green sheet and, therefore, the ceramic green sheet was swollen or partly dissolved, whereby voids were generated at the interface between the ceramic green sheet and the spacer layer or cracks and wrinkles were generated on the surface of the spacer layer and voids were generated in the ceramic green chip fabricated by laminating the multi-layered units to form a laminated body and baking the laminated body or portions of the spacer layer where cracks and wrinkles were generated dropped off during the lamination of the multi-layered units, whereby voids were liable to be generated in the ceramic green chip after baking, while limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate and d-dihydrocarvyl acetate used as the solvent of the dielectric paste for forming the spacer layer in Working Examples 1 to 6 hardly dissolved polyvinyl butyral contained in the dielectric paste used for forming the ceramic green sheet and it was possible to prevent cracks and wrinkles

from being generated on the surface of the spacer layer and prevent voids from being generated in the ceramic green chip after baking.

[0188]

Further, it was found from Working Examples 1 to 7 and Comparative Examples 1 and 2 that in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and the mixed solvent of terpineol and kerosene (mixture ratio (mass ratio) of 50:50) as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, and in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and terpineol as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, the short-circuit failure ratio of the multi-layered ceramic capacitors were extremely high, while in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and limonene as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste

containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and  $\alpha$ -terpinyl acetate as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-dihydrocarvyl acetate as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-menthone as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the

multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-perillyl acetate as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and I-carvyl acetate as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, and in the case where the dielectric paste and the conductive paste each containing a copolymer of methyl methacrylate and butyl acrylate whose weight-average molecular weight was 700,000 as a binder and d-dihydrocarvyl acetate as a solvent were printed on the surface of the ceramic green sheet formed by using the dielectric paste containing polyvinyl butyral whose degree of polymerization was 1450 and degree of butyralization was 69 mol % as a binder, thereby fabricating the multi-layered unit, and the fifty multi-layered units were laminated, thereby fabricating the multi-layered ceramic capacitor, it was found that



the short-circuit failure ratio of the multi-layered ceramic capacitors could be markedly reduced.

[0189]

It is reasonable to assume that this was because the mixed solvent of terpeneol and kerosene (mixture ratio (mass ratio) of 50:50) and terpeneol used as the solvent of the dielectric paste for forming the spacer layer and the solvent of the conductive paste in Comparative Examples 1 and 2 dissolved polyvinyl butyral contained in the dielectric paste used for forming the ceramic green sheet and, therefore, the ceramic green sheet was swollen or partially dissolved, whereby cracks and wrinkles were generated in the ceramic green sheet, while limonene,  $\alpha$ -terpinyl acetate, l-dihydrocarvyl acetate, l-menthone, l-perillyl acetate, l-carvyl acetate and d-dihydrocarvyl acetate used as the solvent of the dielectric paste for forming the spacer layer and the solvent of the conductive paste in Working Examples 1 to 7 hardly dissolved polyvinyl butyral contained in the dielectric paste used for forming the ceramic green sheet and it was therefore possible to prevent the ceramic green sheet from being swollen or partially dissolved and prevent cracks and wrinkles from being generated in the ceramic green sheet.

[0190]

The present invention has thus been shown and described with reference to the preferred embodiments and the working examples. However, it should be noted that the present invention is in no way limited to the details of the described arrangement but changes and modifications may be made without departing from the scope of the appended claims.